Biomass yield stability of switchgrass (*Panicum virgatum L.*) cultivars

R.G. Fuentes*, C.M. Taliaferro
Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, OK 74078
Fax (405) 744-5269; froger@mail.pss.okstate.edu

The development of viable bio-based energy systems offers many potential benefits relative to energy availability, national security, a cleaner environment, and associated economic rewards [4]. Large-scale bioenergy use will require the deployment of environmentally acceptable energy crops and cropping systems for producing large quantities of low-cost, high-quality biomass feedstocks [5]. Switchgrass (*Panicum virgatum L.*)**,** a perennial herbaceous species indigenous over much of the contiguous USA, was chosen by the DOE as the model herbaceous species for development as a bioenergy feedstock crop. It was chosen on the basis of its wide adaptation, high production potential on marginal soils, and tolerance to biotic and abiotic stress agents [2]. Identification and/or development of switchgrass cultivars adapted to different climatic-edaphic environments and having capability for sustained high biomass production and quality are required to ensure successful deployment of the species as a dedicated energy crop. We report here the results from a 7-yr experiment testing the magnitude and stability of biomass yields of nine switchgrass cultivars and three cultivar blends in Oklahoma.

Materials and Methods

The switchgrass cultivars were 'Alamo', 'Kanlow', 'PMT 279', (lowland ecotypes) and 'Blackwell', 'Caddo', 'Cave-in-Rock', 'Late Synthetic High Yield', 'Shelter', and 'Summer' (upland ecotypes). The cultivar blends were Alamo + Summer, Alamo + Kanlow, and Kanlow + Blackwell. Cultivars and blends will be referred to simply as cultivars. In 1993, seeded (10 kg PLS ha^{-1}) sward plots (3m X 6m) were established on research stations near Chickasha (McLain silt loam soil) and Haskell (Taloka silt loam soil), Oklahoma. The experimental design at each location was a randomized complete block with three replications. Plots were fertilized each spring with 78 and 90 kg N ha^{-1} at Chickasha and Haskell, respectively. Beginning in 1994, plots were harvested one time annually, near the end of the growing season. A 6 m^2 area (1m X 6m) from each plot was harvested using a mechanical plot harvester. Total biomass fresh weight per plot was recorded and biomass moisture content for each plot was determined to obtain total biomass dry matter (DM) per plot, which was converted to Mg DM ha^{-1}.

Data were analyzed within and across locations and years using the general linear models procedure of SAS [3]. Stability analyses of the cultivars across the 14 environments (7 years x 2 locations), were conducted using the procedures of Eberhart and Russell [1]. Summer and Shelter were excluded from the analyses of Chickasha data and combined data for the two locations because of stand loss.

Results and Discussion

Satisfactory plot stands were maintained for all cultivars except Summer and Shelter at Chickasha. Cultivars, locations, years and their 1^{st} and 2^{nd} order interactions generally represented significant ($P<0.05$) sources of variation. Cultivar DM differences were significant ($P<0.05$) for all environments except at Chickasha in 1996 ($P=0.19$) and 1999 ($P=0.09$). The two locations differed in DM yield all years except 1995. The overall mean DM yield at Haskell (15.5 Mg ha^{-1}) was higher than at Chickasha (11.4 Mg ha^{-1}), likely reflecting the higher mean annual precipitation received at Haskell. Also, stand deterioration of selected cultivars, principally Summer and Shelter, was much more severe at Chickasha than at Haskell.

When averaged over cultivars, DM yields ranged from 6.7 (1998) to 18.6 (1995) Mg ha^{-1} at Chickasha and 9.7 (1997) to 19.0 (1994) Mg ha^{-1} at Haskell. Mean yield variations over years were closely associated with amount and distribution of precipitation during the growing season; which for both locations was near or above norm for most, but not all, of the 7 years.

Alamo, Kanlow and the blends that they were in produced the highest DM yields at both locations. Shelter and Summer failed to maintain stands at Chickasha and were the lowest yielding cultivars at Haskell. The DM yields of Cave-In-Rock, Caddo, and Blackwell were of similar magnitude at the respective locations. Blending of varieties did not result in definitive performance enhancement relative to the best cultivars grown in monoculture.

The much higher DM yield capability of the robust lowland ecotype cultivars compared to smaller, less robust upland ecotype cultivars is well documented. What is less well documented is the capability of cultivars for long-term sustained high DM production, particularly lowland cultivars on non-alluvial soils or marginal soils, or both. Stand persistence and sustained high biomass production are associated with many factors, major ones being nutrient availability (soil fertility) and tolerance to stresses produced by biotic and abiotic agents. Eberhart and Russell (1966) define a stable cultivar as one with a unit regression coefficient (b) and deviations from regression (S_d^2) as small as possible. Results of the stability analyses indicated relatively stable DM yields for most cultivars, except Summer at Haskell (b=0.393 and S_d^2=1.66). The high mean DM yields and relatively good stability of Alamo (? =14.9 Mg DM ha^{-1}, b=1.13, S_d^2=1.26) and Kanlow (? = 15.4 Mg DM ha^{-1}, b=1.00, S_d^2=1.22) make them choice candidates for use as bioenergy feedstock crops under the conditions tested. Alamo and Kanlow maintained relatively good DM yields during years of lowest mean DM production at Chickasha (1998, ?=6.7 Mg DM ha^{-1}, Alamo=6.7 Mg DM ha^{-1}, Kanlow=7.5 Mg DM ha^{-1}) and Haskell (1997, ?=9.7 Mg DM ha^{-1}, Alamo=13.0 Mg DM ha^{-1}, Kanlow=13.4 Mg DM ha^{-1}).

The results are of practical significance because they demonstrate the ability of adapted switchgrass cultivars for sustained high biomass production with minimal input over a long duration with no reduction in stand and DM production potential.

References

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